NJCAT TECHNOLOGY VERIFICATION

BRICE ENVIRONMENTAL SERVICES CORPORATION

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Introduction

1.1 NJCAT Program

NJCAT is a not-for-profit corporation to promote in New Jersey the retention and growth of technology-based businesses in emerging fields such as environmental and energy technologies. NJCAT provides innovators with the regulatory, commercial, technological and financial assistance required to bring their ideas to market successfully. Specifically, NJCAT functions to:

- Advance policy strategies and regulatory mechanisms to promote technology commercialization
- Identify, evaluate, and recommend specific technologies for which the regulatory and commercialization process should be facilitated
- Facilitate funding and commercial relationships/alliances to bring new technologies to market and new business to the state, and
- Assist in the identification of markets and applications for commercialized technologies.

The technology verification program specifically encourages collaboration between vendors and users of technology. Through this program, teams of academic and business professionals are formed to implement a comprehensive evaluation of vendor specific performance claims. Thus, suppliers have the competitive edge of an independent third party confirmation of claims.

NJCAT has developed and published Technical Guidance Documents containing a technology verification protocol that is consistent with the New Jersey Department of Environmental Protection (NJDEP) Technical Manual and the Interstate Technology and Regulatory Cooperation (ITRC) program technical and regulatory documents. This technology verification review is consistent with the NJCAT general verification protocol contained in the guidance documents.

Pursuant to N.J.S.A. 13:1D-134 et seq. (Energy and Environmental Technology Verification Program) NJDEP and NJCAT have established a Performance Partnership Agreement (PPA) whereby NJCAT performs the technology verification review and NJDEP certifies the net beneficial environmental effect of the technology. In addition, NJDEP/NJCAT work in conjunction to develop expedited or more efficient timeframes for review and decision-making of permits or approvals associated with the verified/certified technology.

The PPA also requires that:

- The NJDEP shall enter in reciprocal environmental technology agreements concerning the evaluation and verification protocols with the United States Environmental Protection Agency, other local required or national environmental agencies, entities or groups in other states and New Jersey for the purpose of encouraging and permitting the reciprocal acceptance of technology data and information concerning the evaluation and verification of energy and environmental technologies; and

The NJDEP shall work closely with the State Treasurer to include in State bid specifications, as deemed appropriate by the State Treasurer, any technology verified under the energy and environment technology verification program.

1.2 Technology Verification Report

In April 2001, Brice Environmental Services Corporation, PO Box 73520, Fairbanks, Alaska, with offices in Ringoes, NJ submitted a formal request for participation in the NJCAT Technology Verification Program. The technology proposed – a water-based soil washing process, described in greater detail later in this report, is a technology that can remediate Small Arms Firing Ranges (SAFRs) of heavy metals, e.g., lead, copper, zinc, and antimony from bullet fragments. The request after pre-screening by NJCAT staff personnel (in accordance with the technology assessment guidelines) was accepted into the verification program. This verification report covers the evaluation based upon the performance claims of the vendor Brice Environmental (see Section 4). Several meetings were held with the vendor and a number of telephone discussions were conducted to solicit relevant materials and to refine specific claims. The evaluation is based on third party prepared reports provided by Brice Environmental.

Pursuant to New Jersey Corporation for Advanced Technology (NJCAT) "General Verification Protocol", acceptable Federal and respective State requirements, such as N.J.A.C. 7:26E, were used to collect samples and analyze the data from the full-scale projects listed in the verification report. Also, the data analysis from each of the full-scale projects was conducted by Federally and State acceptable independent entities that are not affiliated with the applicant.

1.3 Technology Description

1.3.1 Technology Status: general description including elements of innovation/uniqueness/competitive advantage.

Remediation of soils at small arms/skeet ranges, impact areas, and munitions sites presents unique challenges in that contaminants exist as both discrete particles and as sorbed compounds dispersed throughout the soil matrix. For impact area/munitions site soils, the presence of high explosives and propellant constituents and the fact that traditional bio-treatment methods to deal with explosives involve bulking with additional organic material further complicate the process. This approach not only increases the volume of material to be dealt with, but also does nothing to address the toxicity/leachability associated with the particulate metals. To combat the high cost of remediating these soils, Brice Environmental has developed a unique approach that uses soil washing to recover particulate metals from range soils as a refined product, thereby rendering the soil non-toxic from that source and suitable for reuse. For impact area/munitions soils, this approach can also be used as a volume reducing pretreatment step to significantly reduce the volume of material requiring more expensive residual treatment, and remove particulate metals that are both toxic to the bio-regimes, and hazardous due to leachability.

Brice Environmental’s success in the field is attributed to a thorough operations based treatability study prior to any field activities, coupled with extensive project experience treating widely varying soils, and a proven track record in unit operation scale-up and performance.

The treatability studies conducted in Brice Environmental's Fairbanks mineral lab emulates actual field processing steps using scaled down equipment and procedures. By taking this approach, Brice can objectively analyze each site's soil without prejudice, recommend the most effective approach from both a cost and technical effectiveness standpoint, and provide the optimized approach and residuals management strategy for each site prior to mobilization. Using the treatability study results, Brice can ensure predictable performance in scale-up from bench to field based on over 40 years of heavy civil/environmental construction experience.

Removal of the discrete particles as part of a remedial activity not only reduces the total lead, but also the leachable lead accordingly. Unfortunately, though, simple dry screening seldom, if ever, is suitable to remove these lead particles through all of the size ranges where it is present. Dry screening does not differentiate between same-sized lead and stone particles, and it is not practical to dry screen with a screen opening smaller than 3/8 inch to ½ inch. In addition, dry screening is ineffective in deagglomerating "clay balls". As a result, the fine particulate lead with the greatest contribution to leachability is not recovered, and the metal particles that are recovered on the 3/8 inch screen are rarely of high enough purity to allow commercially viable recycling.

Brice Environmental has extensive experience in processing lead-impacted materials and recycling the recovered metals. Brice addresses the above issues through:

- Wet scrubbers/screens for dust-free deagglomeration and sizing
- Multi-stage coarse and fine gravity separations for particulate lead recovery and refinement for recycling
- Compact, high capacity mobile plant modules designed to be moved and easily reconfigured from site to site
- Closed-loop, water-based process with spill controls eliminates airborne lead dust, while minimizing the volume of process water required

The Brice soil washing process uses placer mineral processing techniques and procedures to recover particulate contaminants as refined "products." The operation is dust free, and in the case of ranges, the recovered metal is "scrap metal" per 40 CFR 261.1(c)(6). Under this citation, scrap metal is classified as a "recyclable material" that is not regulated or manifested.

1.3.2 Specific Applicability

The US Department of Defense (DOD) oversees more than 3,000 active small arms firing ranges as well as the closure, or pending closure, of 200 more. Live fire training with high-explosive munitions has resulted in the deposition of spent munitions, propellants, and explosives in impact area soils. In addition to the organic compounds found in propellants and explosives, small arms training results in the deposition of particulate lead and other heavy metals. Also firing points accumulate lead and organic compounds used in initiators and propellants. Depending on site-specific characteristics such as soil type, exposure time, and rainfall, erosion and migration of particulate metal as well as migration of explosive compounds may occur. Contaminants present typically include particulate metals from various types of ordnance as well as a variety of nitroaromatic compounds that were used as propellants and explosives.

Traditional treatment methods for remediating explosives and propellants have incorporated biodegradation techniques. While effective on the organic compounds, this approach does not address the metals, which themselves can be toxic to the bioregimes. Physical treatment (soil washing), however, is a proven treatment technology for removing metals from soil. The technology utilizes water and mechanical energy to slurry the soil and separate it into its constituent particles of rock, gravel, sand, silt, and clay.

Utilizing density separation techniques developed primarily for the gold mining industry, physical treatment recovers particulate metal and unspent ammunition. The removal of the particulate metal results in a dramatic reduction in both total and leachable levels for the heavy metals most commonly involved with munitions, which typically include lead, zinc, copper and antimony.

Physical treatment also partitions the residual organic or sorbed contaminants from the larger soil grains into the organic matter and/or fine soil fraction. For sites where the soil contains appreciable amounts of rock, gravel, and sand, physical treatment can significantly reduce the overall volume of soil requiring more expensive residual treatment and/or disposal for these sorbed contaminants, thereby reducing total project cost. And since contaminants are physically removed, long term monitoring and associated liabilities are eliminated.

1.3.3 Range of Contaminant Characteristics

Brice Environmental has found that the form and distribution of particulate lead varies based on range use, size and impact velocity of the round, soil characteristics, and past range maintenance practices. Skeet ranges generally involve widely dispersed lead particles that fall to the ground with little impact energy. As such, remediation of these ranges involves large soil volumes, with relatively low particulate lead concentrations. Based on the age of the skeet range and soil chemistry however, lead shot can corrode into a wide range of various particle sizes. Since the pellets have little impact energy, fragmentation is not an issue.

Rifle and pistol ranges, however, are the exact opposite with regard to fragmentation. Most training on these ranges is done with fixed or stationary targets at known distances resulting in the formation of “bullet pockets” on the face of the berm. The high impact energy of these high-speed rounds with the rounds accumulated in the bullet pockets result in significant fragmentation and ricochet. To mitigate ricochet problems, standard range maintenance practices have been to “reface”, or turn the berm soil to bury the projectiles below the impact depths of incoming rounds.

As a result of range maintenance activities, particulate lead can be found at depths below traditional impact depths, and the particles present range from whole, relatively intact projectiles to microscopic metal particles. As a result of this heavy accumulation in a relatively small soil volume, coupled with the fine lead present, most of the small arms range soils tested to date have contained high total lead contents and failed standard leachability tests.

1.3.4 Range of Site Characteristics

Brice Environmental's experience has shown that firing range soils vary significantly from site to site, and even at different locations within a given site. Variations in soil that affect treatment procedures include grain size distribution, clay content and physical characteristics, mineralogy, aggregate hardness, soil pH, and the form and distribution of contaminants.
Soil washing recovers the particulate contaminants and classifies soil fractions by both size and density. Through their affinity for soil fines and organic matter, sorbed contaminants, if present, can be partitioned, and the concentrated contaminant-bearing material then segregated from the clean soil fractions for subsequent treatment or disposal. Hence, the volume reduction of material requiring further treatment is a function of the organic/fines content of the soil.

1.3.5 Treatability Study: Sample Collection and Analysis

A thorough treatability study using representative site soils is imperative to determine appropriate treatment methods at any site, as well as to predict actual scale-up and field performance of the selected approach. It is the first step in any soil treatment process. The single most important step in any treatability study is sample collection and preparation. As such, it is not necessarily the size of the sample submitted, but rather the accuracy and representativeness of the sample compared to the whole volume of soil to be treated. This is difficult to achieve as lead contamination at small arms firing ranges presents the following unique challenges:

- Metal contaminants are present as discrete particles ranging in size from intact bullets to bullet fragments;

- Lead bullets striking the impact berms at high speed can actually vitrify on impact, forming "melts" on individual soil particles;

- Lead bullets corrode over time and during rainfall events the surface corrosion dissolves in the water. Percolation of lead contaminated water through the soil column results in soil contamination. The soil contamination is non-homogenous with respect to soil particle size. Soil lead contamination typically increases as a function of decreasing soil granule size; and

- Migration and channeling of contaminated rainwater during heavy rainfall events results in elevated levels of soil contamination within select areas of a small arms range.

Field sampling of small arms ranges thus poses many challenges that render conventional sampling methods insufficient for range soils with particulate contaminants. This necessitates the need for a large number of grab samples from each area of concern through the full depth of the contaminated matrix, which are subsequently composted into bulk samples for testing. Not recognizing the unique features of small arms firing range contamination and applying conventional sampling and analytical techniques will result in widely varying data, making interpretations difficult. Brice Environmental employs a mining-based sampling approach for collecting representative samples.

Contaminated soil samples from firing ranges are usually a heterogeneous mixture of matrix materials and contaminants. Individual granules of the soil samples can be significant relative to the size of a sub-sample taken for analysis so the analytical results can vary considerably depending on the particular group of granules selected in the sub-sample. Variation caused by sub-sampling can be reduced by using a large sub-sample but for heavy metals in particular, the digestion techniques for analysis of total metals usually call for a maximum sub-sample size of only 2-grams.

With no controls over the granules selected for digestion and by ignoring the coarser soil fractions, analytical results for metals in soil can vary wildly. Brice has found that heavy metal contamination, for example, can vary by over two orders of magnitude between the finest soil fraction (minus 200 mesh) and medium sand (10 by 40 mesh) alone. Consequently, one sample that contains more minus 200 will generate a higher total metal result than a sample, which contained more 10 x 40 soil and so forth. In summary, for an accurate determination of soil contamination the sample analyzed has to contain the same fractional soil percentages (gradation) as the raw soil.

The situation regarding an accurate determination of soil contaminant levels is further compounded by the presence of particulate metal and organic matter. Clearly, particulate metal presents a significant source of variation when analytical sub-samples are limited to several grams. Organic matter (leaves, sticks, grass, etc.) can also present a source of variation however because it functions as a contaminant “sink” for organics and inorganics. Brice has found metal contamination in organic matter to be as high as three orders of magnitude above the contamination level of the soil at some sites, thus the impact of varying amounts of organic matter in the small sub-sample being analyzed can be significant.

Brice Environmental has developed cost-effective field-sample collection and reduction approaches that incorporate the required sample size to help control the adverse effects of sample heterogeneity. These approaches include:

- For impact berms at rifle and pistol ranges an excavator test trench is used in selected locales. A composite sample representing the vertical soil column and lead contamination can then be collected from the walls and floor of the excavation. The vertical extant of lead contamination is typically driven by the visual presence of particulate lead. With this approach the quantity of soil requiring treatment can be approximated.

- For trap/skeet ranges typically only the top 6 inches to 1 foot of soil is contaminated. Excavating a series of small areas within the range can be performed with an excavator or shovel, based on the size of the area, and the nature of the soil.

- The soil collected from each of the above approaches is placed on a large tarp. The sample is then “rolled” and homogenized by lifting corners of the tarp and mixing the soil. With two people, over 300-lbs. of soil can be mixed using this approach. A 5-gallon sub-sample is then taken with a garden trowel from numerous random points.

The actual sampling steps employed are site specific and a function of particulate lead distribution and soil gradation. A stratified sampling approach, done by dividing the area to be sampled into more homogeneous groupings may be required to reduce variation in analytical results. Impact berms containing obvious bullet pockets with large depositions of lead, skeet ranges containing discrete areas of heavy lead shot accumulation, and firing ranges which utilized different soil types in the construction of the impact berm and range floor, are examples in which a stratified sampling approach may be required.

The approach developed by Brice to accurately determine feed soil and post-treatment soil contaminant levels is as follows:

- Perform no composite soil analyses but rather, fractional analyses

- Remove all particulate metal and organic matter from the specific fractions prior to any fractional analyses

- Analyze the particulate – and organic-free soil fractions individually for the listed contaminants

- Increase the sample size for the conventional total metals acid digestion method to 8 grams

- Weight-average the fractional soil analytical results with the percentage contribution of each fraction to derive the composite feed soil contaminant concentrations

- Add the percentages of particulate metal from each fraction to derive the total percentage in the feed soil. Add the lead and copper determinations for the particulate metal to the feed soil concentrations

- Add the percentages of organic matter from each fraction to derive the total percentage in the feed soil. Weight-average the contaminant contribution from the organic matter and add to the feed soil concentrations

- Multiple the contaminant concentrations found in the water used for each sample with the volume of water used and add to the feed soil concentrations

By using larger sub-sample sizes and removing particulate metal and organic matter from the soil for separate analysis, soil contaminant concentrations will be more accurately derived. These sample preparation and analysis approaches will help to control the adverse affects of sample heterogeneity and reduce the coefficient of variation in analysis results.

It is important to recognize that when designing a sampling plan for small arms firing ranges that:

- Uncertainty will never be reduced to zero, and

- The money spent collecting samples to reduce uncertainty should be balanced against the value of the reduced uncertainty.

1.4 Project Description

This project involved the evaluation of four third-party assembled reports on field testing of Brice Environmental's soil washing process to verify that the Brice process meets their performance claims.

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2. Evaluation of the Applicant

2.1 Corporate History

Brice Environmental was established by Brice Incorporated, a Fairbanks-based, family-owned construction firm founded in 1961. For more than 40 years, Brice Inc. has built infrastructure such as roads, runways, and harbors in rural "bush" Alaska. Throughout that time, Brice has established a reputation for overcoming the logistical challenges posed by Alaska's vast size, remote location, and harsh climate.

Seeing the growing need for waste management and soil remediation services nationwide, the officers at Brice Inc. formed Brice Environmental Services Corporation in 1991. Their staff of engineers, planners, and designers provide in-depth, hands-on experience working as a team to provide turnkey services. Brice Environmental believes in taking a "no-net-waste" approach to remediation whereby all materials are either reused on site, or commercially recycled as products. Their expertise covers the development and implementation of innovative, cost-effective approaches to on-site treatment in addressing site remediation challenges.

2.2 Organization and Management

Brice Environmental Services Corporation's principal office is located in Fairbanks, Alaska, 99707 with Sam R. Brice as its President and Craig Jones as Vice President, Brice Environmental operates an eastern region office in Ringoes, NJ 08551.

2.3 Operating Experience with respect to the Proposed Technology

The technology and skill sets used in remedial soil washing are based heavily on commercial mining and soil classification operations. Brice mines and processes material on almost every construction project undertaken as there are no commercial sources in the remote villages where the work takes place. In addition, Brice owns and operates a fixed-base quarry that processes over 150,000 tons of sand and aggregates annually. To date, the Brice team has mined, dredged, and/or processed over 4,000,000 tons of soil/sediments, of which 45,000 tons involved soil washing/particulate lead recovery with residual treatment as required.

Brice Environmental's recent soil washing project experience includes four (4) full-scale Small Arms Firing Ranges (SAFRs) and/or artillery impact area remediations, and treatability studies conducted at more than 50 contaminated firing/skeet range sites.

2.4 Patents

Brice Environmental's soil washing process is not a patented technology. While the individual unit operations equipment is generally commercially available, the process configuration and operations procedures were developed by and are proprietary to Brice Environmental.

2.5 Technical Resources Staff and Capital Equipment

The treatability study testing is performed at Brice Environmental's Fairbanks, Alaska facility. Operating under DFR 40 Part 261.4, (EPA ID #AKR000000653), the facility is equipped with analytical and mineral processing equipment.

For each sample submitted for testing, the study includes a step-wise evaluation of:

- Feed soil total and leachable lead levels
- Soil grain size analysis
- Particulate lead distribution by grain size fraction
- Particulate lead removal by size segregation and gravimetric techniques
- Final total and leachable lead levels
- Evaluation of metal concentrates for recycling

In the event site cleanup goals are not met after initial particulate lead removal, Brice evaluates a series of proprietary follow-on treatment methods to supplement the initial soil washing process. These include:

- Bioremediation of organic compounds, including explosives and propellants

- Froth Flotation
- Chemical Leaching
- Emulsion Stabilization of both organic and residual metal compounds
- Phytoremediation
- Chemical Oxidation/Reduction

Only the soil fraction(s) failing reuse criteria need to undergo these additional treatment steps. This affords a cost savings through volume reduction, as soil washing generally partitions sorbed organic and metal contaminants into the finer soil fractions, while rendering the sand and coarser fractions suitable for reuse after particulate removal. Results of the treatability study dictate the appropriate treatment approach for implementing the full-scale remediation. Treatment effectiveness and implementability are presented in the treatability study report. The report also includes the most appropriate means of handling the recovered metal.

In addition to the soil washing technology, Brice Environmental has earned a reputation for getting the job done, and not compromising product quality and performance under the toughest of conditions such as the Drift River, AK and Deering, AK emergency response projects, which earned a National Engineering and USACE Performance award respectively. Both involved rapid mobilization to inaccessible sites, on-site mining and processing, and severe schedule restraints. Both were completed ahead of schedule and within the approved budgets.

3. Treatment System Description

While the concept of soil washing is over 100 years old, Brice Environmental pioneered its application in remediating metals-impacted soils in the early 1990's. Since that time, the process has been refined and the equipment streamlined to provide higher throughputs from a physically smaller plant. A description of each processing step follows.

Physical Sizing – The physical sizing process uses sequential wet screening steps, the first of which is deagglomeration. Wet screening provides dust-free operation and sharp particle-size fraction separation (cut) points. For each screening step, "plus" and "minus" fractions are generated, with actual cut points based on the treatability study data. The goal of wet screening is to partition the particulate metal contamination into narrow size fractions to facilitate effective gravity separation and to partition the soil particles with organic contaminants into the smallest size fraction for subsequent classification.

Soil Classification/Attrition – Sand screws are used to classify sand and gravel fractions by scrubbing contaminant coatings off the particle surfaces and segregating the contaminant-bearing organic matter (humates) and soil fines from the clean sand and gravel fractions. The goal of classification/attrition is to minimize the volume of material requiring subsequent treatment while maximizing the output of clean soil fractions. With sand screws, water flow coupled with screw rotational speed determines the level of attrition scrubbing and subsequent particle size of the fines fraction that is removed from the clean sand fraction.

Gravity Separation – When particulate contaminants are the same size as the surrounding soil particles, gravity separation/density treatment is used to remove the particulates from the same-sized soil matrix. For a typical soil matrix, particulate contaminants usually consist of humates (specific gravity of 0.8 to 1.2) and metals (specific gravity of 8 or more based on metals present). With a specific gravity of 2.5 to 3.5 for typical soil fractions, the particulate contaminants, which are lighter and/or heavier than the same-sized soil particles, are easily separated using mining-based density separation techniques of elutriation and jigging.

Elutriation and jigging are used for humates/soil fines removal and gross particulate removal, respectively. Elutriation uses water flow over weirs to separate the lighter humates and soil fines from heavier/larger sand particles. Jigging uses differential settling in water to separate heavy, metal particles from same-size, but lighter, sand/gravel particles. This approach has been successfully used in both commercial mineral processing and small arms firing range remediation.

Magnetic Separation – To recover artillery fragments and other spent ferrous metal components, self-cleaning magnets are used. They are suspended over the intermediate product conveyors, and automatically remove potentially contaminated tramp iron and other ferrous metals from the product stream after the initial high-pressure wash, depositing the iron in a bin for subsequent recycling. This ensures that the treated soil is free of any magnetic material.

Dewatering/Water Treatment – To reduce water consumption, process water is recycled within the plant. A clarifier and dewatering screen are used in series to segregate/dewater heavy humates and condition the fines-slurry for subsequent dewatering using a belt filter press. Sand and carbon filtration follows as a polishing step for final rinse spray bars. This enables a counter-current reuse of process waters while minimizing water consumption and associated disposal costs.

Humate removal – A static organic removal screen is incorporated after each classification/elutriation step to recover the “floatable” humates in the aqueous stream. In addition, a high frequency vibratory screen is used after the initial fines dewatering step to remove the “heavy” humates from the fines stream prior to belt filter press dewatering. All of the recovered humates are containerized for subsequent treatment and/or disposal.

4. Technical Performance Claims

Claim 1 – Brice Environmental’s water-based soil washing particulate recovery process is effective in removing particulate metal contaminants from Small Arms Firing Ranges, resulting in typical lead contaminant reductions of 90 percent in the treated soil, with the recovered metals suitable for commercial recycle.

Claim 2 – Brice Environmental’s water-based soil-washing process effectively separates the soil fines and/or organic matter (humates) fractions containing sorbed contaminants from the coarse fractions, thereby reducing the volume of material requiring secondary treatment. The soil quantity meeting the clean up goal following soil-washing alone is a function of the soil fines/humates fraction. Typically the soil available for reuse following the soil-washing process is in the 70 to 100 percent range.

Claim 3 – Brice Environmental's soil washing process coupled with residual secondary treatment has been shown to be effective in rendering 100 percent of the treated soil suitable for reuse on site.

5. Treatment System Performance

Brice Environmental has conducted soil washing/particulate lead recovery processing on 45,000 tons of contaminated soil with residual treatment as required. Brice Environmental has performed treatability studies at more than 50 contaminated firing/skeet range sites. Importantly, over the past four years Brice has completed four (4) full-scale Small Arms Firing Ranges (SMFRs) and/or artillery impact area soil washing remediations. The results from these four (4) projects are documented in final reports, treatability studies and published papers, and provide the foundation upon which Brice Environmental's performance claims are evaluated.

5.1 Full-Scale Soil Washing Projects

The four full-scale soil washing projects are briefly described below. These descriptions are intended to provide a history of the site, the entity responsible for the remediation effort, the specific objectives for the demonstration, the unit processes employed in the soil-washing plant, and the time and duration of the project. Additional information on each project is summarized in Table 1.

Project 1 – Small Arms Firing Range 24, Fort Dix, New Jersey (Ref. 1-4)

U.S. Army Tank-automotive and Armaments Command, Armament Research, Development and Engineering Center (TACOM-ARDEC), Picatinny Arsenal, NJ, engineers are addressing small arms training range remediation under a new program called RangeSafe. Traditional small arms projectiles were predominantly a lead/antimony alloy with a copper jacket. When subjected to bullet-to-bullet impacts, or a harsh environment, migration of toxic heavy metals from the range berm may occur. Previous studies testing stabilization methods on active berms without particulate metal removal were ineffective, and in some cases, made the problem worse.

RangeSafe was established by the Army to help commercialize emerging environmental technologies targeting the management, recovery and mediation of residual contaminants generated throughout the life cycle of armament systems. The RangeSafe concept was initially developed as a companion to the Green Bullet Program, which has successfully developed lead-free small arms ammunition for subsequent deployment.

The technical approach used for this project involved physically removing the lead from the soil prior to green bullet conversion. To accomplish this, placer mining techniques were employed in a soil washing process to remove the particulate metals for subsequent recycling. The soil was then conditioned through the soil washing process for subsequent use as "ballistic sand" on the impact berm.

Oversize stones, excessive fines, and other deleterious materials were segregated and selectively removed to mitigate ricochet hazards and simplify future maintenance activities. The lead-free, conditioned soil was then returned to the range berm as ballistic sand and restricted to Green Bullet usage. This approach eliminated toxic metals from berm soils, allowing for green bullet conversion without costly disposal or the long-term liability of leaving the lead in place.

The National Defense Center for Environmental Excellence (NDCEE), operated by Concurrent Technologies Corporation, was tasked by the U.S. Army TACOM-ARDEC to demonstrate physical treatment followed by phytoremediation at Small Arms Firing Range 24, Fort Dix, New Jersey. Brice Environmental was selected by the NDCEE to be the physical treatment contractor for the project.

Specific objectives for the physical treatment demonstration included:

- Processing a minimum of 3,500 tons of lead contaminated soil
- Recycling wash water within the plant in a closed system
- Reducing total lead levels in the treated soil stockpile to a maximum total soil lead concentration of 600 milligrams per kilogram (mg/kg), with a desired lead level of no more than 400 mg/kg.
- Generating a recovered lead product suitable for recycling under a bill of lading.

The unit process system deployed at Range 24 consisted of a series of mining-based treatment units integrated into one continuous process. Bench-scale treatability study results indicated that site soils were composed primarily of sands containing an oversize fraction of plus 10-mesh particulate metal, rock, and vegetation. Therefore, the first step in the process approach was to process the feed soils over a wet vibrating screen deck that was equipped with a 10-mesh (0.07-inch) screen.

Soil was fed into the plant through a grizzly/feeder and was subsequently conveyed to the wet vibrating screen deck via a conveyor equipped with a belt scale for recording the production rate and daily tons of soil processed. The plus 10-mesh fraction, consisting of rock, particulate metal, and vegetation, was then conveyed into a density treatment circuit to concentrate and recover the metal.

Following density treatment for the removal of the particulate metal, the plus 10-mesh fraction, now consisting only of rock and vegetation, was dewatered and discharged to the treated soil stockpile. The minus 10-mesh fraction, consisting of the fine sand, silts and clays, was transferred to a clarifier where a coagulant was added to settle the material from the water. The settled fraction was then discharged onto a high frequency screen deck for final dewatering and discharge to the treated soil stockpile.

Brice Environmental mobilized equipment to the site beginning on August 29, 1999, and erected the physical treatment plant within the confines of Range 24. Soil processing commenced on September 10, 1999 and continued until September 29. Demobilization of the treatment plant commenced on September 30, 1999 and the plant was demobilized from the site on October 12.

Project 2 – Massachusetts Military Reservation (MMR), Cape Cod, MA (Ref. 5-7)

The Massachusetts Military Reservation (MMR) is located on Upper Cape Cod, approximately 60 miles from Boston. The Reservation was constructed in 1935, although the area had seen periodic military use since 1911. The impact area of the ranges used for past military training activity at MMR sits directly above the only aquifer to supply ground water to Cape Cod.

Firing range berm solids from 16 ranges used for small arms (pistols and rifles) and larger caliber weapons training were stockpiled at the MMR during previous maintenance activities. Typically, munitions used at these ranges included small arms rounds (5.56 mm, 7.62 mm, and 9 mm) and some large rounds, such as from 50-caliber machine guns. These munitions often consisted of a lead core in a metal alloy jacket. Metals used in these rounds are lead, copper, iron, nickel, and antimony. These rounds often fragment upon impact and produce metal residuals, from complete slugs to microscopic fines in the sandy soils of the berm and areas nearby. Lead is the primary contaminant of concern because of the levels in berm soils and the potential for lead to leach into groundwater. This soil had been previously dry screened using a ¼-in. screen. The dry screening process was planned to separate the berm soils into two fractions. The ¼-in. plus fraction (i.e., that material retained on the screen) was anticipated to be mostly lead and other metallic fragments (i.e., up to 70% lead), suitable for recycling. The ¼-in. minus fraction (i.e., that material that passed through the screen) which was anticipated to be mostly soil, was than to be stabilized as an interim maintenance activity to reduce the leachability of the lead. Once treated, the ¼-inch minus material was replaced on the berm. During the implementation of the dry screening, the existing berm soils were "clumped" and did not readily pass through the dry screen. This resulted in significantly more soil material being retained in the ¼-in. plus materials than anticipated. The ¼-in. plus fraction contained approximately 1.5% lead (as compared to anticipated lead content of 70%) which was not acceptable for recycling. In addition, since the lead in the ¼-in. minus materials was present in the form of free particulates, it was impossible to effectively stabilize the material. Two options to remedy the situation were explored – offsite disposal as a hazardous waste, and soil washing to remove particulate metals.

The soil washing alternative offered distinct advantages in that it eliminated the long term liability associated with disposal as all treated materials could be reused in a beneficial fashion on site. In addition, the particulate metals recovered would be a "refined" product with a commercial salvage value, and the estimated cost of the soil washing approach was roughly half the cost of the disposal alternative.

PEER Consultants, P.C., was contracted to complete the soil maintenance action. PEER subcontracted with Brice Environmental Services Corporation to employ their soil washing process. The objective of the MMR soil washing project was to remove the particulate lead and other metallic fragments from the existing ¼-in. plus stockpiled material. The stockpile consisted of lead/projectile fragments, geologic materials, and organic matter. Approximately 30% of the material was ¼-in. minus agglomerates which did not pass through the ¼-in. dry screen used in the previous stabilization attempt.

The scope of activites to be conducted included:

- Wash oversize cobbles to remove ¼-in. minus agglomerate.
- Wet screen to de-agglomerate and segregate the ¼-in. minus material from the material requiring particulate lead removal.
- Remove particulate metals from the ¼-in. plus material.

The soil washing processing plant employed at MMR included three major components:

- A "grizzly"/scrubber separation unit
- A gravity separation unit; and
- A water clarification module.

The treatment sequence involved transporting the stockpiled berm soils to the treatment unit intake. The soils were processed through the various units, using process feed water to assist in the washing and screening units. The resultant treatment process separated the soil feed materials into several size grades and material types:

- ¼-in. minus soil
- settled fines
- ¼-in. to ¾-in. cobbles
- ¾-in. to 4-in. cobbles
- 4-in. plus cobbles
- ¼-in. plus lead (and other metallic fragments)

The ¼-in plus lead fraction was recycled; the soil washing process water was treated on-site using a clarification module to provide process water feed as needed, and settled fines from the clarifiication module were tested by extraction using the TCLP and analyzed for lead.

Mobilization to the site was initiated on October 12, 1999; processing occurred during October 25 – November 19, 1999; and the last contractual action on the site occurred on December 14, 1999, with the pick-up of the last of the residual process water.

Project 3 - Marine Corps Air-Ground Combat Center (MCAGCC), 29 Palms, CA (Ref. 8-10)

The Marine Corps Air Ground Combat Center (MCAGCC), located in south central San Bernardino County, California, is an active military facility. In 1940, the Army began using the Base to train glider crews and, beginning in 1943, fighter pilots. The Navy used the facility for bombing and gunnery ranges until the end of World War II. The Base was not in use between 1945 and 1952, but has been occupied by the Marine Corps since 1952.

In support of the primary mission of MCAGCC, troops are trained and qualified in the firing of rifles and pistols. The small-arms range complex trains over 10,000 active duty Marines per year for service rifle and service pistol requalification. In addition, approximately 1,500 reserve Marines, local law enforcement personnel, Junior Reserve Officers Training Corps cadets, and recreational shooters use the small-arms ranges each year.

In 1996 and 1997, the Naval Facilities Engineering Service Center (NFESC) performed an initial site assessment of some of the small-arms ranges at MCAGCC. Results from the **rifle range** indicated that the highest total lead concentrations were in the impact berm and the area immediately behind the impact berm, with detected values of up to 35,000 mg/kg (all reported values from NFESC are after removal of visible lead fragments). The concentrations fell rapidly with distance behind the impact berm, falling to less than 1,000 mg/kg within 250 feet of the berm.

At the **pistol range**, the highest total lead concentrations were also in the impact berm, with detected values up to 4,300 mg/kg. As expected, the impact berm at the **Battle Sight Zero (BZO) range** also had the highest total lead concentrations, with detected values up to 14,000 mg/kg. The concentrations behind the impact berms of both these ranges again fell rapidly with distance.

Lead concentrations also fell rapidly with depth. A location with a total lead surface concentration of 26,000 mg/kg had a concentration of 700 mg/kg two feet below ground surface. Based on the depth profile data and the surface data, the lead at the small-arms ranges is essentially immobile except when surface materials are carried away by wind and water erosion.

The overall scope of this proactive lead removal and pollution prevention project included removing and processing contaminated soils from the three small-arms ranges to remove the lead, then installing bullet traps at those ranges as a pollution prevention measure. These ranges were in active use supporting weapons practice and qualifications requirements at MCAGCC. The following ranges were specified for this project:

- Range 1: Known-Distance Rifle Range (“Rifle Range”)
- Range 1A: Battle Sight Zero Range (“BZO Range”)
- Range 2: Known-Distance Pistol Range (“Pistol Range”)

During the first phase of this project, Battelle characterized the ranges, performed an Environmental Assessment, established a soil processing goal for total lead concentration based on a Human Health Risk Assessment, performed treatability studies, designed a soil management pad, and selected the appropriate soil processing technology. During the second phase, Battelle constructed the soil management pad, removed contaminated soils from the ranges, selected and managed the soil processing vendor, constructed infrastructure, and installed bullet traps at each of the three ranges.

Before selecting the soil processing technology, it was necessary to establish the goal that the processing technology would need to achieve. Because this range maintenance and repair work was performed on an active range, the EPA Military Munitions Rule (40 CFR Part 260) applied, and the soils were not considered hazardous waste under the Resource Conservation and Recovery Act (RCRA). The local regulators were also in favor of adopting this position, and did not apply the California hazardous waste regulations (CCR Title 22). Consequently, the soil processing technology did not have to meet the leachability and total metals criteria that would otherwise apply if the soils were classified as hazardous waste and were being disposed of off site. In addition, because the range will continue as an active range, criteria for cleanup scenarios in which the land might be returned to residential, commercial, or other military use did not apply.

To select the soil-processing vendor, Battelle conducted an initial review to identify vendors capable of providing the needed services. More than 70 vendors were contacted to request information on capabilities, prior experience, and budgetary cost estimates for a range of services relevant to the planned range maintenance activities. The twenty-five responses received were screened to identify vendors to receive the performance specification and request for proposal (RFP). Five vendors were selected to receive RFPs, and three responded. Brice Environmental Services Corporation was the vendor selected.

Bench-scale treatability study test results indicated that the majority of the lead contamination ranged in size from large intact bullets and bullet fragments (¾ inch to ¼ inch) to sand-size (50 mesh) metal particles. Therefore, the development of the physical treatment system was directed at a system for free particulate recovery in the ¾ inch to 50-mesh size range. The plant subsequently deployed on site was based on the treatability study results, and consisted of ten (10) individual unit operations integrated into one continuous plant.

Since the treatability study results indicated that site soils were composed primarily of sands and rock, the process approach was designed to separate rock larger than ¾ inch and sand smaller than 50 mesh from the soil fraction containing the targeted particulate metals. To accomplish this, a wet vibrating screen deck containing a ¾ inch screen (Step 1) was utilized to remove large particulate-free rock. A second smaller screen (No. 4 mesh) on the vibrating screen deck was utilized to separate the larger particulate metal and rock from the fine soil fraction. Fine particulate metal and fine soil (minus 4 mesh), along with the wash water passed through the smaller screen deck.

The minus ¾ inch by plus 4-mesh metal and rock (Step 2) was subjected to density treatment. Following density treatment the separated rock was discharged to a dewatering sandscrew (Step 3) and discharged from the plant.

The slurry of material which passed through the second screen was pumped to a separate density treatment unit (Step 4) for fine particulate metal recovery. Refining the metal in this fraction was crucial in order to maximize the value of the material. Recovered metals from this step were thus discharged to two additional density recovery units in order to enhance the purity of the metal (Steps 5 and 6). The concentrates from these units, along with the concentrates from

Step 2 were discharged into a metal dewatering unit (Step 7). From this unit the concentrate was discharged into a supersack.

Soil fines discharging from Step 4 were split into clay and fine sands in another dewatering sandscrew (Step 8). Density treated sands from Step 5 and 6 were also discharged to the dewatering sandscrew for dewatering. Soil clays exiting the sandscrew were pumped into a clarifier (Step 9) where a coagulant was added in order to accelerate the settling rate of the clays. The dewatered clay was then pumped to a centrifuge for additional dewatering (Step 10). All of the soil fractions were recombined and placed into a daily stockpile.

The bench-scale treatability study was completed on June 30, 1998. Mobilization of equipment to the site began June 8, 1998, and shakedown testing began at the end of June. Full-scale operations commenced in early July and continued until September 19, 1998.

Project 4 – Small Arms Firing Range 5, Ft. Polk, LA (Ref. 11)

Physical separation and acid leaching is an innovative remedial alternative at sites where metals are present as particulates, e.g., small-arms ranges. Brice Environmental Services Corporation has developed and commercialized acid leaching processes to recover lead from soils. Physical separation is the first step in the commercial process. The lead-laden fines are then processed by acid leaching.

Brice Environmental performed a pilot-scale treatment demonstration on soils from Range 5 at Fort Polk, an Army Base near Leesville, Louisiana, under subcontract to Battelle. Range 5 is an active 300-meter small-arms range that has been used mainly for M-16 rifle training. The range has three berms, the last of which runs along the edge of a wetland. Fort Polk was selected for the demonstration because it is environmentally proactive and has active ranges that contain soil and metals accumulation of the type and quantity typically found at several DoD ranges. The demonstration was conducted in an old parking lot approximately 2 miles away from the range by road. The demonstration site was located some distance from the range to avoid closing adjacent ranges, whose cones of lethal fire (surface danger zones) extend into Range 5. Also, the demonstration site was located near an available power supply.

The separation/leaching technology demonstration at Range 5, Fort Polk was a joint effort between the Naval Facilities Engineering Service Center (NFESC) and the U.S. Army Environmental Center (USAEC). The field activities related to the demonstration were conducted between August and December 1996. During this period, two vendors demonstrated their variations of the technology. At the request of USAEC and NFESC, Vendor I used acetic acid leaching and Vendor 2 (Brice Environmental) used hydrochloric acid leaching. Battelle, under contract to NFESC, conducted the independent evaluation of the technology and its application at Fort Polk.

The scope of work required the successful demonstration of a soil-washing and soil-leaching technology suitable for the removal of particulate and ionic heavy metal contamination from the shooting range soils. To perform a definitive demonstration, the scope of work required that up to 1,000 tons of shooting range soils be treated using a continuous, closed-loop process.

Specific objectives of the demonstration included:

- Operation of the plant with continuous throughput rate of 5 tons/hr.
- Cycling of wash/leachant water within the plant in a closed system
- Reduction of total lead levels in treated soil to less than 500 mg/kg
- Reduction of TCLP lead in the treated soil to less than 5 mg/L
- Process treatment of plant water to less than 5 mg/L lead and a neutral pH, for discharge to the base sewage treatment plant.
- Recycling of all lead removed from the soil

Regarding the physical treatment approach, bench-scale treatability study test results (August 1996) indicated that on a mass basis, the majority of the lead contamination consisted of large intact bullets and bullet fragments, with minor amounts of sand-size metal particulates. Therefore, the development of the physical treatment system was directed at a system for free particulate recovery.

Regarding chemical treatment, bench-scale treatability study test results indicated that leaching of the entire soil fraction was required following physical treatment. Bench-scale results indicated that while retention time in the same leach solution provided effective leaching of the settled soil fraction (sands), removal of lead from the fines fraction (soil clays) required a series of contacts with fresh leachant.

The unit process system treatment train deployed on site consisted of physical and chemical system components integrated into one continuous process. Initially, the process approach was designed to physically remove large particulate metal using a wet vibrating screen deck and water (Step 1) to maximize physical removal and minimize the amount of heavy metals solubilized in subsequent leaching steps.

Once mobilization was complete, a small amount of soil was processed prior to the validation test to confirm the treatment approach and representativeness of bench-scale samples upon which the treatment train was predicated. It quickly became obvious that feed soils varied when compared to the bench-scale treatability study sample soils. Excavated feed soils contained a high percentage of clays with an extremely high plasticity, whereas bench-scale sample soils did not. Processing feed soils on the vibrating wet screen deck resulted in clay-ball formation regardless of attempts to improve performance by adding water. Utilizing the screen deck would have resulted in the formation of clay balls. The clay balls would have fouled the large particulate recovery unit with a mat of clay. The modification made in the field prior to commencement of the validation test consisted of removing the screen deck and bypassing the density treatment process planned for recovery of large particulate metal.

Following physical treatment for the removal of large particulate metal, the soil fraction was submerged in a leaching solution (Step 2), attrited, and sized to separate soil clays from sands, while the sands fraction was density treated for removal of fine particulate metal (Step 3). Clay fines separated at Step 2 were then contacted with fresh leachant in a series of clarifiers (Step 4) and dewatered (Step 5). Sands were retained in leachant followed by dewatering (Step 6). After leaching and dewatering, the sands and clays were recombined, mixed, neutralized, and discharged (Step 7). Physical removal processes consisted of two mineral jigs for recovering large and fine particulate metal for placement into barrels. Metal recovery from the leaching system was achieved with a single precipitation clarifier (Step 8). Heavy metals recovered from the leachant as a precipitant were then dewatered using a recessed plate-frame filter press (Step 9) and discharged into 10-yard, roll-on/roll-off boxes. Leachant flow to the precipitation clarifier came from leachant overflow from the clarifiers in Step 4. Clean leachant was returned to the leaching circuit via delivery lines to all leaching components.

The aggressive work schedule finalized prior to the demonstration reflected a contract agreement that emphasized production and minimized delays and down time. However, it also increased overall costs. Two weeks were allocated for placing and configuring equipment, testing for leaks, and filling plant components with material. Subsequently, a one-day validation run required nine hours of continuous operation. Three days of down time for analytical testing confirming treatment success followed the validation run. After process validation, sixteen days of processing followed during the period 15 November – 6 December, 1996.

Table 1 provides a concise overview of the four full-scale soil-washing projects described above. Summarized in Table 1 for each project are the range use/maintenance practice, description of the soil, the soil characterization data, target contaminant, contaminant concentration (and range), clean-up goal, and range reuse objective. Of particular note is the wide variation in soils, contaminant concentrations and clean-up goals.

5.2 Verification procedures

Brice Environmental has been selected to perform full-scale soil washing remediation at four (4) Department of Defense small-arms firing ranges scattered throughout the United States (Massachusetts, New Jersey, Louisiana, and California). In three instances Brice was the soil-washing subcontractor for the remediation effort. The entity responsible for the remediation effort (PEER Consultants, Battelle, National Defense Center for Environmental Excellence) provided the QA/QC procedures for the project. In the case of the fourth project MCAGCC, Brice Environmental utilized its own QA/QC procedures in generating the data. The above referenced reports provide the basis for verification of Brice Environmental's claims.

Claim 1 – Brice Environmental's water-based soil washing particulate recovery process is effective in removing particulate metal contaminants from Small Arms Firing Ranges, resulting in typical lead contaminant reductions of 90 percent in the treated soil, with the recovered metals suitable for commercial recycle.

Since all four projects had as an objective the recovery of metals suitable for commercial recycle these projects provide data that can be evaluated to assess the validity of Claim 1. These data are shown in Table 2. The effectiveness of the technology is most readily measured by comparing the average total lead concentration in the feed soil to the average total lead concentration of the treated soil. For example, for the Fort Dix project, of the 21 tons of metal recovered via physical treatment, 84 percent or 17.64 tons were determined to be lead. (Note – Eighty-four (84) percent lead in recovered metal is the average Brice has measured from all treatability studies and remediation projects.) The balance of the metal recovered for recycling consisted of copper, zinc, and antimony. Dividing 17.64 tons of lead by the total amount of material processed (3,591 tons) results in an average percentage of particulate lead from the feed soil of 0.4912 percent (4,912 mg/kg). Adding the particulate lead concentration and the residual total lead concentration measured in the treated soil (396 mg/kg) results in the feed soil containing an average total lead concentration of 5,308 mg/kg. Thus the particulate lead removal efficiency is 92.5 percent [(4912 ÷ 5308) x 100]

In the case of MMR, the concentration of lead in the soil and the fines was not measured. Hence the initial and final contaminant concentrations can not be determined. However a lower limit of the initial lead concentration can be determined from the total metal recovered. A total of 50 tons of lead and other metals were recovered and transported to the recycling facility. In accordance with the Work Plan, a minimum of one sample for lead assay was required per 100 tons of recovered lead. Two samples were collected from the recovered lead and other metallic materials. The lead assay results indicated lead concentrations of approximately 60 percent. This lead percentage is lower than typically found in other projects, and is attributed to the fact that the samples contained lead recovered from the 50-caliber range (50-caliber training rounds have a lower lead content than most small arms munitions). Hence Table 2 shows an initial lead concentration > 4,820 mg/kg ([50 x 0.6 ÷ 6224] x 10^6). Since the clean-up goals were “no visible lead in the ¼ plus fraction” and for the ¼ minus fraction “TCLP < 0.75 mg/l”, the lead concentration in the soil following soil-washing is unknown. Hence the following approach was used to estimate the particulate lead removal efficiency. On the basis that the treatability study indicated that > 98.4% of the particulate metal was contained in the ¼ plus soil fraction, and the washed ¼ plus soil exhibited zero visible lead, a particulate lead removal efficiency in excess of 98% is shown in Table 2.

At MCAGCC, approximately 11,700 tons of soil were processed and 207 tons of metals were recovered, approximately 85% of which was lead. Processed soils were analyzed in daily batches with a resulting average residual lead level for the treated soil of 1,796 mg/kg. Hence the initial lead concentration in the soil was determined to be 16,834 mg/kg ([207 x 0.85 ÷ 11,700] x 10^6 + 1796) and the removal efficiency 89.3 percent ([15038 ÷ 16,834] x 100).

Regarding the Ft. Polk soil-washing project, since the treated soil contaminant level was only reported for the soil following secondary treatment, the contaminant level after soil-washing alone is unknown. Therefore, the particulate lead removal efficiency was calculated by subtracting the percent (in raw soil) of lead remaining in the organic matter, precipitate sludge and processed soil from 100 percent. This yielded 89.3%. The Battelle report, however, indicated that the recovered Pb from the coarse fraction to be > 90% of Pb in raw soil. The 89.3% is reported in Table 2 as the most conservative removal efficiency.

These data support the portion of the claim: "resulting in typical lead contaminant reductions of 90 percent in the treated soil". Table 2 also indicates that significant quantities of "metals suitable for commercial recycle" were recovered and sent for recycling.

Claim 2 – Brice Environmental's water-based soil-washing process effectively separates the soil fines and/or organic matter (humates) fractions containing sorbed contaminant from the coarse fractions, thereby reducing the volume of material requiring secondary treatment. The soil quantity meeting the clean-up goal following soil-washing alone is a function of the soil fines/humates fraction. Typically the soil available for reuse following the soil-washing process is in the 70 to 100 percent range.

Table 3 indicates the soil quantity meeting the clean-up goal following the soil washing process, i.e., prior to any secondary treatment. In calculating the soil suitable for reuse percentage, one must first subtract the metal recovered/recycled (tons) and other material recovered with the metal from the total contaminated soil processed. For the Ft. Dix project, the entire soil (100%) met clean-up goals following the soil washing process. Similarly at MCAGCC, all the soil remaining after the recovered metal concentrate (230 tons) met the clean-up goal of 5400 mg/kg. Hence no further treatment was required. At the MMR site, 599 tons (9.7%) of the soil (i.e. fines) failed the < 0.75 mg/l TCLP leaching criteria and required further treatment. The Ft. Polk project resulted in the highest percentage (32.9%) of the raw soil undergoing secondary treatment. This was a consequence of the nature of the integrated soil-washing process, where all fines were subjected to acid leaching, whether or not this secondary treatment step was required. The composite treated soil, both the coarse (soil-washed only) and treated fines, significantly achieved the clean-up goal (165mg/kg v. 500 mg/kg). The data in Table 3 support Claim 2.

Claim 3 – Brice Environmental's soil washing process coupled with residual secondary treatment has been shown to be effective in rendering 100 percent of the treated soil suitable for reuse on site.

Table 4 indicates for those two sites where secondary treatment was required or demonstrated, the quantity of soil following soil washing requiring secondary treatment, the secondary treatment process, and the treated soil available for reuse. In both cases soil-washing coupled with secondary treatment rendered all of the soil suitable for reuse on site. In the case of the 261 tons of stabilized soil (TCLP < 0.75 mg/l) at MMR, its reuse was restricted to an active berm. This reflected concerns regarding the long-term effectiveness of the stabilized soil and a reluctance to allow its unrestricted reuse. In regard to the 266 tons of acid leaching treated soil at Ft. Polk, the treated soil had no restrictions placed on its reuse. However, since soil was required to rebuild an active berm on-site, it was reused for this purpose.

6. Technical Evaluation Analysis

6.1 Verification of Performance Claims

Based on a review of the performance data from Brice Environmental's four small-arms firing range soil-washing projects, sufficient data exists to support Brice Environmental Claims 1,2 and 3.

6.2 Limitations

Soil washing can be employed at any small-arms firing range (SAFR). Soil washing is a source removal technology that physically separates particulate metals from the soil matrix and refines them such that they have a commercial salvage value. The system treats SAFR soils by removing spent bullets and bullet fragments from the soil through a physical solids-separation technology, then treating the remaining soil, if required, with the appropriate secondary treatment approach. The decision to remediate by soil washing depends primarily on economics.

Treatment of small arms ranges utilizing soil-washing technology fits a mining-type economic model based on mass production. The volume of soil is the driving force behind treatment costs on a per-ton basis. Typical of a mass production model, cost elements such as mobilization/demobilization, labor, and capital outlay decrease in a non-linear fashion, on a per-ton basis, with increased quantity.

Small arms firing ranges are highly variable with respect to soil and contaminant characteristics. Treatment goals and the quantity of soil requiring treatment are highly variable as well. A number of variables impact treatment costs when considering this technology for full-scale implementation at small arms firing ranges. Site-specific variables are listed below, with discussion on their particular impact to treatment costs. These variables include:

- Mass of soil to be processed
- Cleanup standards
- Soil characterization (grain size distribution and chemistry, including contaminant by fraction analysis)
- Site assessment risks
- Split- or single-operations site
- Throughput rate required
- Weather conditions/time of year to operate
- Level of personal protection equipment (PPE) required
- Availability and cost of utilities
- Sampling and sample preparation

Mass of Soil to be Processed -Physical treatment costs on a per-ton basis are tied directly to the quantity of soil requiring treatment along with elements of production rate (or capital outlay) and labor. The technology is a mining process capable of high production rates and becomes increasingly cost competitive when the volume of soil requiring treatment is 10,000 tons or greater. Labor is one of the biggest cost elements and, typical of a mining process, labor does not increase proportionally with plant scale. Hence, as the production rate increases, the cost of labor on a per-ton basis decreases. Capital outlay is a major cost element. Capital costs for a larger plant with a higher production rate are offset by large quantities of material and reduction in total project labor costs.

Cleanup Standards - Cleanup standards for total lead are typically site-specific and based on risk assessment in lieu of nationally set standards. The level established for a particular site is important because it affects whether or not physical treatment will be effective as a stand-alone technology.

Soil Characterization - Variations in soil structure, gradation, chemistry and contaminant concentrations result in treatment processes that are site (and cost) specific and cannot be universally applied. Plastic clays require highly specialized attrition equipment, while the percentage of clay affects the scale of the clay dewatering system. Soil at one site may contain some gravel, while soil at another site may only contain sands, silts, and clays. The cation exchange capacity of clays influences the buffering capacity of the soil. One site may contain a high level of leachable lead due to acidic soil conditions, while another site may contain predominately particulate lead due to more neutral soil conditions.

Although sand, silt, and clay are the predominant soil matrices used in berm construction, the examples above show that one type of treatment process cannot be applied to all small-arms shooting ranges. The ideal treatment plant approach is to utilize unit components pre-determined by the bench-scale treatability study as required for insertion in the overall treatment process.

Site Assessment Risks - The locale chosen for treatment operations influences costs. Locating near offices or other populated areas may affect operational hours (schedule) due to noise associated with treatment operations, i.e., loaders, trucks, etc. Treatment locations near rivers and streams may result in additional environmental protection measures as well. A highly visible project may result in additional treatment costs due to the need for maintaining an appearance beyond that normally required. Site security is another important aspect in evaluating site costs. Although operations may be secured within a fence and locked gate, security personnel may be required.

Split- or Single-Operations Site - Locating treatment operations within the small arms shooting range is ideal because the complete process of excavation, haulage, treatment, and replacement can be readily scrutinized and performed more efficiently compared to split operations. Hauling soil off the range on roads is invariably more expensive. Timing for hauling feed soil and treated soil becomes critical as well. Most importantly, additional regulations and their associated cost impacts may come into play when treatment operations are performed outside of the firing range area.

Typically, a 30 ton-per-hour plant offers the lowest treatment costs for under 25,000 tons of material. At volumes above 25,000 tons, implementing a treatment plant capable of a throughput rate of 40 tons-per-hour or more offers significant cost savings with increasing quantities of soil. High production operations require increased attention to logistics for timely delivery of soil for processing, adequate storage space for treated soils, and replacement of treated soils.

Weather Conditions/Time of Year to Operate - Operations must be scheduled with local weather conditions in mind. Operations performed during extremely hot months impact treatment costs by limiting the duration personnel can work in direct sunlight. Scheduling operations for rainy months can potentially impact treatment costs with project delays if no provisions are made. In addition, personnel have to cease operations during periods of severe thunderstorms. Cold weather is invariably difficult to work in and can halt production altogether.

Level of Personal Protection Equipment (PPE) Required - PPE requirements are based on the health and safety requirements for the contaminants and hazards associated with the soil treatment process. As the level of worker protection increases, more time is spent suiting up and less time processing. Regarding PPE, health hazards of concern include lead contaminated dust inhalation and dermal contact. Based on air sampling and post-worker physicals, protection consisting of coveralls, rubber boots, safety glasses, hard hat and gloves are adequate for worker protection. When PPE requirements are higher than those described above, treatment costs are higher because of decreased worker efficiency and increased PPE costs.
Availability and Cost of Utilities - Utilizing existing utilities is invariably cheaper than having to provide them. Tying into a fire hydrant is a very convenient means of providing water to fill plant components and supply make-up water. The typical type of electricity required for the treatment plant is 460-Volt, 3-phase power. Generators can be provided for plant power, and water can be hauled in via tanker truck. Depending on plant scale, costs for these utilities will typically add several dollars per ton to the processing costs, hence vendor-supplied utilities will increase the treatment costs.

Sampling and Sample Preparation Procedures - Proper sampling and sample preparation methods must be used when dealing with soils containing particulate metal ranging in size from intact bullets to very fine fragments. These methods are necessary to reduce sample variation and ensure adequate material representation. Treatment costs will be significantly higher than if mining-based sampling and sample preparation techniques are not utilized. The risk of having to reprocess treated soils deemed failures due to non-representative sampling or inappropriate sample preparation forces the vendor to increase treatment costs.

7. Net Environmental Benefit

The New Jersey Department of Environmental Protection (NJDEP or Department) encourages the development of innovative environmental technologies (IET) and has established a performance partnership between their verification/certification process and NJCAT's third party independent technology verification program. The Department in the IET data and technology verification/certification process will work with any New Jersey-based company that can demonstrate a net beneficial effect (NBE) irrespective of the operational status, class or stage of an IET. The NBE is calculated as a mass balance of the IET in terms of its inputs of raw materials, water and energy use and its outputs of air emissions, wastewater discharges, and solid waste residues. Overall the IET should demonstrate a significant reduction of the impacts to the environment when compared to baseline conditions for the same or equivalent inputs and outputs.

The obvious environmental benefit of the Brice Environmental water-based soil-washing process is that a majority of the contaminated soil (70 – 100%) can be reused on site, while metal is recovered for recycle. The alternative would be to dispose of the contaminated soil in a hazardous waste landfill, thus consuming a limited resource that might better be utilized for more difficult to manage wastes. In addition, the process has no liquid effluent.

To assess the NBE, the Brice soil-washing process is compared to three alternatives: I) Dig, haul and dispose of the contaminated soil in a hazardous waste landfill (Subtitle C) where the landfill operator will stabilize before landfilling, II) Stabilize (phosphate addition) on site (ex-situ) and dispose in a municipal waste landfill (Subtitle D), or III) Stabilize (phosphate addition) either ex-situ or in-situ and dispose on-site. Alternative III is not a permanent remedy and would require long-term monitoring and a deed restriction on the property. Also, this alternative may not be acceptable at some sites, e.g., Pinelands. It should be recognized that for small sites the most timely and cost-effective alternative will be disposal at a Subtitle C landfill. In making the NBE determination, the following assumptions and information were utilized:

<u>Brice Soil Washing Process</u>

250 KW needed to run a 30 ton/hour plant (8.3 KWh/ton) – from Brice Environmental

22 lb Pb recovered/ton soil processed (Average of the 4 projects assessed assuming metal recovered is 84 percent lead) – Table 2

<u>Lead mining</u> (Currently there is only one company mining lead in the U.S.)

Cost to mine - \$20/ton (typically 10% Pb) – from Brice Environmental

Energy cost to mine - \$5/ton (assumed 25% of total)

Smelting cost - \$260/ton (generally after enriched to 50%)

<u>Phosphate Stabilization</u>

100 gal of diesel fuel to operate equipment that stabilizes (ex-situ) 800 tons of lead contaminated soil (from Russ Sattler – RETECH)

50 gal of diesel fuel to operate equipment that stabilizes (in-situ) 800 tons of lead contaminated soil (from Russ Sattler – RETECH)

Bulking factor (increase in amount of treated soil) – 2 to 3 % (Russ Sattler – RETECH)

<u>Hauling</u>

Truck Capacity – 22 tons

Truck fuel (diesel) economy – 6 mpg

Diesel truck emissions – 22.38 lb CO_2 /gal (from NJDEP)

<u>Other</u>

Energy cost - \$0.067/KWh (from DOE, 1999 – Average of CA, LA, MA, & NJ)

Energy to remove contaminated soil for soil washing, stabilization or transportation to landfill the same.

Average PJM grid emission (1999) – 1.1 lb CO_2 /KWh (from NJ DEP)

Net Beneficial Effect

Energy to soil wash – 8.3 KWh/ton

Energy to mine/recover the equivalent metal in one ton of processed contaminated soil (28 lbs) from raw ore.

\$20/ton x 0.25 + \$260/ton = \$265/ton or \$265/200 lb Pb = \$1.325/lb Pb

\$1.325/lb Pb ÷ \$0.067/KWh = 19.78 KWh/lb Pb

19.78 KWh/lb Pb x 22 lb Pb/ton soil = 435 KWh/ton

Energy/emissions to stabilize soil: (ex-situ)

100 gals x 22.38 lb CO_2/gal ÷ 800 tons = 2.80 lb CO_2/ton (2.55 KWh/ton)

Energy/emissions to transport soil to a landfill and clean-fill back to site to replace removed soil (KWh equivalence to CO_2 emissions)

22.38 lb CO_2/gal ÷ 6 miles/gal = 3.73 lb CO_2/mile (3.39 KWh/mile)

The energy/emissions savings for a SAFR remediation can be significant. As an example, for alternative I, assuming 500 miles to the nearest HW landfill and 50 miles to truck in clean soil the energy/emissions savings are:

NBE = 435 KWh/ton + 3.39 KWh/mile x 550 miles ÷ 22 tons

+ 2.55 KWh/ton – 8.3 KWh/ton = 514 KWh/ton (565 lb CO_2/ton)

Some representative NBE's are shown below for the various alternatives. The variation between alternatives is small, since the dominant contributor to NBE is the energy/emissions savings from the recovered metal.

Alternative I

Soil Processed	Total Transportation	NBE	NBE

(tons)	Mileage (miles)	(KWh)	(lb CO_2)
1,000	550	514,000	565,000
10,000	550	5,140,000	5,650,000
25,000	550	12,850,000	14,125,000

Alternative II

Soil Processed (tons)	Total Transportation Mileage (miles)	NBE (KWh)	NBE (lb CO_2)
1,000	50	437,000	481,000
10,000	50	4,370,000	4,810,000
25,000	50	10,925,000	12,025,000

Alternative III (ex-situ treatment)

Soil Processed (tons)	Total Transportation Mileage (miles)	NBE (KWh)	NBE (lb CO_2)
1,000	-	429,000	472,000
10,000	-	4,290,000	4,472,000
25,000	-	10,725,000	11,800,000

Alternative III (in-situ treatment)

Soil Processed (tons)	Total Transportation Mileage (miles)	NBE (KWh)	NBE (lb CO_2)
1,000	-	428,000	471,000
10,000	-	4,280,000	4,710,000
25,000	-	10,700,000	11,775,000

8. References

1. Demonstration of RangeSafe System at Ft. Dix, NJ (Range 24) – Physical Treatment Summation Report, National Defense Center for Environmental Excellence (NDCEE), December 13, 1999.

2. Demonstration of RangeSafe System at Ft. Dix, NJ (Range 24) – Quality Assurance/Quality Control Plan, Revision 1, National Defense Center for Environmental Excellence (NDCEE), July 26, 1999.

3. Average Lead Content in Range 24 Soil, Certified Testing Laboratories, Inc, September 10, 1999.

4. Range 24 Soil Characterization, from Craig Jones, Brice Environmental Services Corporation, May 24, 2001.

5. Firing Range Berms Soil Maintenance Action Completion Report, Camp Edwards Training Site, Massachusetts Military Reservation, PEER Consultants, P.C., May 2000.

6. Work Plan for Soil Maintenance Action Project, Massachusetts Military Reservation, Army National Guard Training Site, Camp Edwards, Massachusetts, PEER Consultants, P.C., May 1999.

7. Results of Physical Treatment Treatability Study, Small Arms Firing Range Soils, Massachusetts Military Reservation, Camp Edwards, Massachusetts, Letter from Craig Jones and Carl Benson, Brice Environmental Services Corporation to Dean Nelson, PEER Consultants, P.C., October 23, 1998.

8. Physical Treatment of Heavy Metal Contaminated Soil at Small Arms Ranges, Marine Corps Air Ground Combat Center (MCAGCC), 29 Palms, Final Report, Brice Environmental Services Corp., 1998.

9. MCAGCC Small Arms Range Raw Soil Characterization, From Craig Jones, Brice Environmental Services Corporation, May 24, 2001.

10. Michael F. Warminsky, Adapting Remedial Technologies to Meet Site-Specific Risk-Based Clean-up Goals; A Case Study of the MCA/GCC 29 Palms Range Soil Remediation Project, Presented at the NDIA 25th Environmental Symposium and Exhibition, March, 1999, Denver, CO.

11. Final Implementation Guidance Handbook, Physical Separation and Acid Leaching to Process Small-Arms Range Soils, Battelle, September 18, 1997.

TABLE 1 – FULL-SCALE FIELD SOIL WASHING APPLICATIONS

Site (Year)	Range Use	Range Maintenance Practice	Soil Description	Soil Characterization %	Target Contaminant	Contaminant Concentration Average/Range[1] (mg/kg)	Clean Up Goal (mg/kg)	Range Reuse Objective
Ft. Dix, NJ 1999	Small arms firing range	Refaced berm w/additional native soil	Sandy	Oversize – 0 Gravel/sand – 92.6 Fines – 7.4	Lead /Lead Particles	5,308 210-38,000	600 (400[2])	Green Ammunition Firing Range
MMR, MA 1999	Small arms firing range	None	Sandy w/cobbles	Oversize – 69.7 Gravel/sand – 21.7 Fines – 8.6	Lead /Lead Particles	> 4820[5]	¼ + (no visible) ¼ - (TCLP <0.75 mg/l)	Green Ammunition Firing Range
MCAGCC, CA 1998	Small arms firing range	None	Sandy/ Gravel	Oversize – 18.5 Gravel/sand – 72.9 Fines – 8.6	Lead /Lead Particles	16,834 27,000 – 233,000[3]	5,400	Bullet Trap/Small Arms Training
Ft. Polk, LA 1996	Small arms firing range	None	Silty sand/ clay	Oversize – 2.2 Gravel/sand – 64.9 Fines – 32.9	Lead /Lead Particles	4117[4] 2743-5194[4]	500 TCLP < 5 mg/l	Small Arms Training

1 - Average is actual field average calculated from the total lead recovered and lead remaining in treated soil. Range is from treatability studies.
2 - Desired level
3 - Prior Battelle site characterization analysis
4 - Actual average field data from the 16 daily analyses
5 - See text for explanation.

TABLE 2 – PARTICULATE METAL REMOVAL EFFICIENCY AND TOTAL METAL RECOVERED/RECYCLED (CLAIM 1)

Site	Soil Processed (Tons)	Target Contaminant	Feed Soil Contaminant Level (mg/kg)	Treated Soil Contaminant Level (mg/kg)	Particulate Metal Removal Efficiency-%	Total Metal Recovered/Recycled (Tons)
Ft. Dix, NJ	3,591	Lead/Lead Particles	5,308	396	92.5	21
MMR, MA	6,224	Lead/Lead Particles	> 4820[1]	¼ + (zero visible) ¼ - (0.095 – 8.6 mg/l)	> 98[1]	50
MCAGCC, CA	11,700	Lead/Lead Particles	16,834	1796	89.3	207[2]
Ft. Polk, LA	835	Lead/Lead Particles	4117	165[3] 2.0 ± 0.29 mg/l[3]	89.3	9

1 - See text for explanation
2 - Twenty-three (23) tons of non-metal residue was recovered along with 207 tons of metal in the “recovered metal concentrates”.
3 - Processed soil composite after secondary treatment

TABLE 3 –PERCENTAGE OF PROCESSED SOIL MEETING CLEAN UP GOAL FOLLOWING SOIL-WASHING (CLAIM 2)

Site	Soil Processed (Tons)	Target Contaminant	Soil Meeting Clean Up Goal (Tons)	Soil Suitable for Reuse (%)	Soil Requiring Disposal/Secondary Treatment (Tons)
Ft. Dix, NJ	3,591	Lead/Lead Particles	3,570	100	0
MMR, MA	6,224	Lead/Lead Particles	4,974 (1/4 +) 599 (1/4 -)	90.3	601
MCAGCC, CA	11,700	Lead/Lead Particles	11,470	99.8	0
Ft. Polk, LA	835	Lead/Lead Particles	560[1]	67.1	266

1 - Non-fines only. Fines were not analyzed prior to secondary treatment. It is assumed that all the fines would have failed the clean-up goals.

TABLE 4 – SECONDARY TREATMENT OF RESIDUAL CONTAMINATED SOIL (CLAIM 3)

Site	Soil Requiring Disposal/Secondary Treatment (Tons)	Soil Disposed (Tons)	Secondary Treatment Process	Soil Treated (Tons)	Treated Soil Available for Reuse (Tons)[1]
Ft. Dix, NJ	0	NA	NA	NA	NA
MMR, MA	601	0	Stabilization	601	601[2]
MCAGCC, CA	0	NA	NA	NA	NA
Ft. Polk, LA	266	0	Acid Leaching	266	266[3]

NA- Not applicable

1 - The quantity of soil, following secondary treatment, that met the clean-up goals.
2 - This soil was reused on site with the restriction that it only be reused on an active berm.
3 - Since this treated soil exceeded the TCLP clean-up criteria, there were no restrictions on its reuse. However, it was reused on-site in an active berm, rather than bring in soil to rebuild the berm.